

**THE 2006 CAPE CANAVERAL AIR FORCE STATION RANGE REFERENCE ATMOSPHERE MODEL VALIDATION  
STUDY AND SENSITIVITY ANALYSIS TO THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION'S SPACE  
SHUTTLE**

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- NASA's Space Shuttle utilizes atmospheric thermodynamic properties to evaluate structural dynamics and vehicle flight performance impacts by the atmosphere during ascent.
- Statistical characteristics of atmospheric thermodynamic properties at Kennedy Space Center (KSC) used in Space Shuttle Vehicle assessments are contained in the Cape Canaveral Air Force Station (CCAFS) Range Reference Atmosphere (RRA) Database.
- Database contains tabulations for monthly and annual means ( $\mu$ ), standard deviations ( $\sigma$ ) and skewness of wind and thermodynamic variables.
  - Wind, Thermodynamic, Humidity and Hydrostatic parameters
  - 1 km resolution interval from 0-30 km
  - 2 km resolution interval 30-70 km
- Multiple revisions of the CCAFS RRA database have been developed since initial RRA published in 1963.
  - 1971, 1983, 2006
- Space Shuttle program utilized 1983 version for use in deriving "hot" and "cold" atmospheres, atmospheric density dispersions for use in vehicle certification analyses and selection of atmospheric thermodynamic profiles for use in vehicle ascent design and certification analyses.
- During STS-114 launch preparations in July 2005 atmospheric density observations between 50-80 kft exceeded density limits used for aerodynamic ascent heating constraints in vehicle certification analyses.
- Mission specific analyses were conducted and concluded that the density bias resulted in small changes to heating rates and integrated heat loading on the vehicle.
- In 2001, the Air Force Combat Climatology Center began developing an updated RRA for CCAFS.



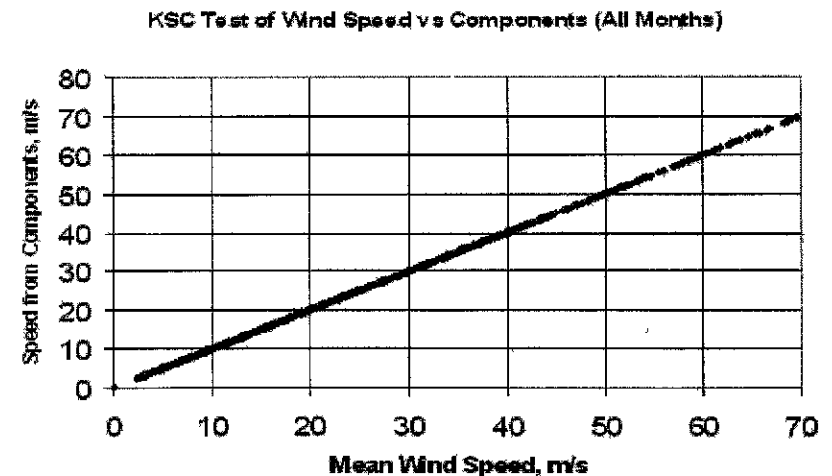
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Efforts during STS-114 mission coupled with an updated CCAFS RRA necessitated work to determine impacts to the Space Shuttle vehicle performance using data from the 2006 CCAFS RRA versus the 1983 CCAFS RRA.

1. Natural Environments Branch at Marshall Space Flight Center (MSFC) began independently validating the statistics derived in the 2006 CCAFS RRA to insure data was physically realistic, statistically coherent and analytically consistent with previous datasets.
2. Ascent/Descent Flight Design Team with United Space Alliance (USA) at Johnson Space Center (JSC) assess how the Space Shuttle vehicle flight performance is impacted by 2006 CCAFS RRA.

### 2006 CCAFS RRA Validation Study

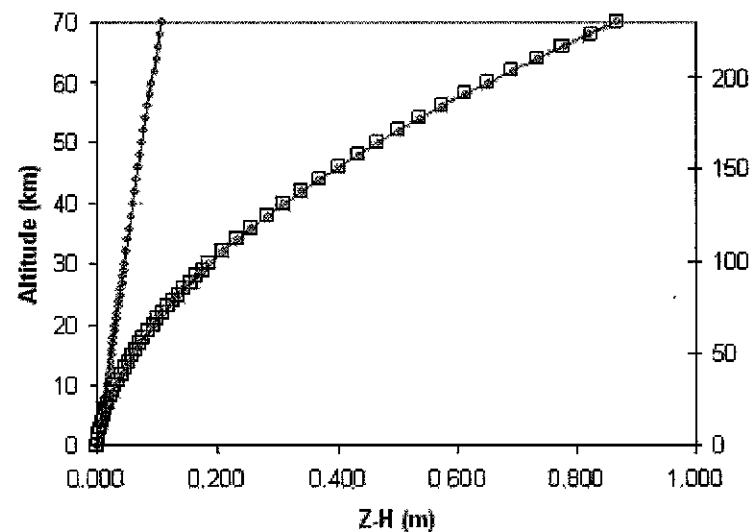
1. Wind Speed and Component Statistics Consistency Test
2. Altitude-Geopotential Height Relationship Test
3. Gas Law Constant Check
4. Dataset Difference



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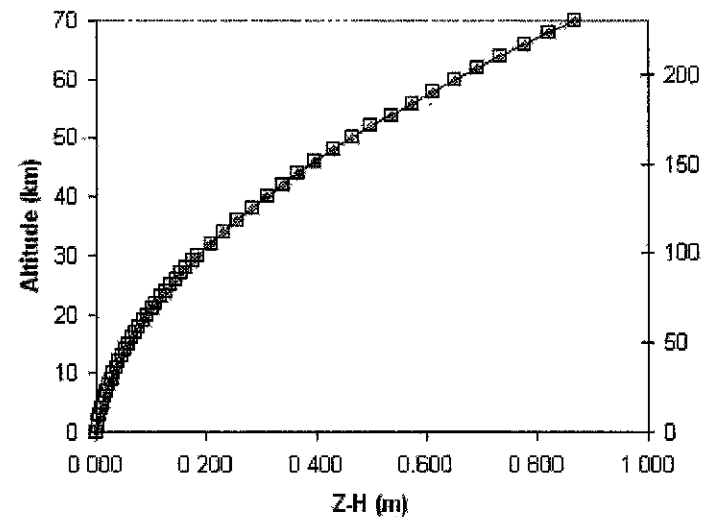
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**Geometric minus Geopotential Height (2006 validation phase)**



**Before**

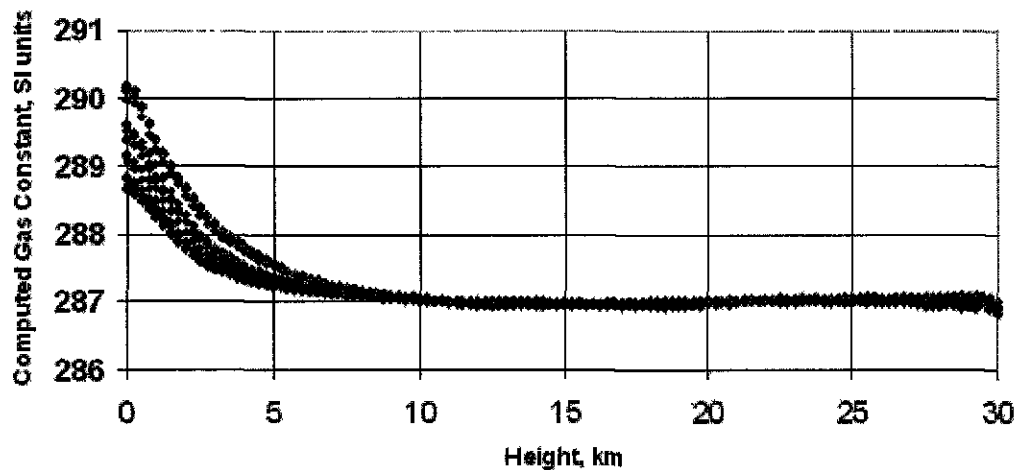
**Geometric minus Geopotential Height (2006 release)**



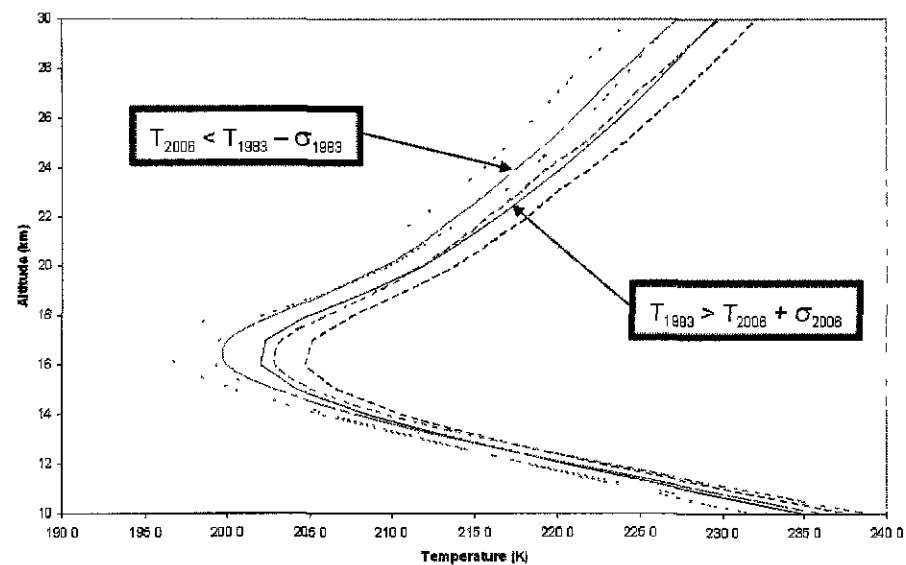
**After**

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KSC Gas Law Test (All Months)



October Temperature Comparison



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## Impact to Space Shuttle Ascent Performance

- Five sets of simulations were ran utilizing the 1983 and 2006 monthly mean atmosphere and concurrent profile databases which are part of the 1983 and 2006 CCAFS RRA.

Atmosphere	Wind & I-loads	RRA 1983	RRA 2006
Mean + 150 profiles	Mean + 150	X	X
Mean + 150 profiles	Mean	X	X
Mean + Full 90 kft Mean database			X

- Results from simulations were assessed against all launch Go/No-Go indicators with statistics derived for the following criteria:

- Measure Wind Simulation
- Performance (Mass to Orbit)
- Quality Assurance Rule
- Maximum Dynamic Pressure

Performance Delta (lbs) mean of 150 Atmospheres RRA 2006 Minus RRA 1983

January	-48
February	-91
March	-51
April	-52
May	-37
June	-66
July	-54
August	-69
September	-86
October	-61
November	-94
December	-92
Average	-67

Performance Delta (lbs) Mean Minus Measured Atmosphere

	2006, 150	2006, Full	1983
January	-35	-43	0
February	-53	-63	-60
March	-1	-10	-52
April	-6	-6	-58
May	10	6	-110
June	-13	-19	-79
July	-29	-32	-83
August	-24	-35	-94
September	-17	-36	-49
October	-12	-6	-73
November	-14	-21	-109
December	-43	-58	-52
Average	-20	-27	-68



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## Conclusion

- Impacts to Shuttle ascent performance is minimal.
- However, analysis required to ensure changes observed with database used in vehicle certification analyses did not adversely impact vehicle.
- 2006 CCAFS RRA is being used in design studies for future NASA launch vehicles.

